# Vitamin C Stability during Preparation and Storage of Potato Flakes and Reconstituted Mashed Potatoes

X.Y. WANG, M.G. KOZEMPEL, K.B. HICKS, and P.A. SEIB


## ABSTRACT

High performance liquid chromatography with electrochemical detection was used to follow losses of L-ascorbic acid (AsA) in the processing and serving of fortified mashed potatoes. Cumulative losses of AsA were: 56% for adding AsA to freshly mashed potatoes at 251 ppm (wet basis); 82% drum-drying the potatoes; 82% storing the flakes 4.3 months at 25°C, and 96% reconstituting mashed potatoes and holding them 30 min on a steam table. The mashed potatoes at the point of ingestion would contain 10 ppm AsA (wet basis), and one serving size (100g) would provide 2% of the adult RDA. Fortification with equivalent levels of magnesium L-ascorbate 2-monophosphate (AsMP) or sodium L-ascorbate 2-polyphosphate (AsPP) gave overall cumulative losses of 20 or 32%, respectively. Such reconstituted mashed potatoes contained 201 ppm and 171 ppm AsA respectively, and one serving would provide about 33% of the RDA of vitamin C.


Key Words: potato flakes, rehydration, vitamin c, drum drying

## INTRODUCTION

POTATOES rank first among vegetables for per capita consumption in the USA (50–55kg/person/yr); they supply about 25% of the recommended dietary allowance (RDA) of vitamin C (L-ascorbic acid, AsA). Potatoes are also the most processed vegetable.

The loss of vitamin C in the processing of raw potatoes to dehydrated flakes has been reported as 30–100% on pilot-scale equipment (Cording et al., 1961; Sullivan et al., 1985). Most of the loss was due to leaching and oxidation. On a commercial scale, vitamin C loss was reported to be about 50% (Augustin et al., 1979). Storage loss of vitamin C in fortified potato flakes and in fresh potatoes was 50–64% after 6-7 mo (Cording et al., 1961; Bring et al., 1963). Reconstituting potato flakes to mashed potatoes and holding them on a steam table caused an additional 30% loss of vitamin C after 30 min at 77–82°C (Augustin et al., 1981).

Adding powdered L-ascorbic acid to dehydrated potato flakes is generally unsuccessful because of segregation of the solids. For that reason, fortification of potato flakes is generally done by adding AsA to the mashed potatoes prior to drum drying. Sullivan et al. (1985) reported that when drying was done immediately after fortifying the mash, little loss of vitamin C occurred.

Two phosphorylated forms of L-ascorbic acid are available commercially, L-ascorbate 2-monophosphate and 2-polyphosphate (Liao and Seib, 1990). At pH 3, 6, and 8, the 2-phosphorylated derivatives are more resistant to air oxidation than ascorbic acid by one, two, and three orders of magnitude, respectively. The 2-phosphorylated derivatives are biologically available (Machlin et al., 1979; Grant et al., 1989), and they have been approved for use in aquatic feeds, but not in foods.

The objectives of our investigation were: (1) to compare losses of AsA and its 2-phosphorylated derivatives added to hot riced potatoes (70°C) that were drum-dried within 45 min, (2) to compare the storage losses of vitamin C in potato flakes that were stored at 25, 35, and 45°C in plastic bags up to 12 mo, and (3) to compare losses of vitamin C during reconstitution and holding of the mashed potatoes on a steam table up to 60 min.

## MATERIALS & METHODS

POTATOES were Russet Burbank harvested in Aroostook County Maine in October, 1989 and stored at about 3°C. L-Ascorbic acid was from Fisher Scientific (New Jersey), L-ascorbate 2-monophosphate magnesium salt from Showa Denko K.K. Ltd. (Tokyo), and L-ascorbate 2-polyphosphate sodium salt mixed with sodium phosphate salts ("STAY-C) from Hoffmann-La Roche (Basel, Switzerland). L-Ascorbate 2-monophosphate magnesium salt and STAY-C (aqueous solution with specific gravity about 1.24 g/mL) were found to contain, respectively, 44.4g and 8.41g equivalents of AsA per 100g on an "as is" weight basis. Glycerol monostearate (emulsifier) and t-butylhydroquinone (Tenox) (antioxidant) were obtained from Eastman Chemical Product, Inc. (Kingsport, TN). Sodium bisulfite and sodium acid pyrophosphate were reagent grade. Oriented polypropylene was a gift from Printpack (Grand Prairie, TX).

### Assays

Moisture content was determined by weight loss upon oven-drying 1 hr at 130°C (AACC, 1968). L-Ascorbic acid and its 2-phosphorylated esters were assayed by high performance liquid chromatography with electrochemical detection (Wang et al., 1988). AsA was assayed directly, whereas AsMP and AsPP were subjected to phosphatase digestion and the released AsA measured. The method gives quantitative recovery of known amounts of standards. All assays were done in duplicate.

### Fortification of potato flakes

Potato flakes were produced on pilot-scale equipment at the Eastern Regional Research Center as previously described (Sullivan et al., 1985). Four batches (45 kg each) of cooked potatoes were collected in series after the continuous ricer.

A base mixture of t-butylhydroquinone (3g), sodium acid pyrophosphate (25g), glycerol monostearate (30g), non-fat dry milk (1g), and sodium bisulfite (0.25g) was prepared by adding those dry ingredients to water (200 mL). The mixture was then mixed with a freshly prepared aqueous solution (200 mL) of one of the forms of vitamin C. All solutions of vitamin C contained the equivalent of 64 mmoles of L-ascorbic acid, or 11.3g of the free vitamin. Batch 1 (Blank) contained the base mix only; Batch 2, L-ascorbic acid (11.3g); Batch 3, L-ascorbate 2-monophosphate magnesium salt (25.4g); and Batch 4, STAY-C (134g). The magnesium salt of L-ascorbate 2-monophosphate was difficult to redissolve in hot water, and required heating to 60°C.

Each batch (45 kg) of hot potatoes from the ricer was collected in the bowl of a Hobart mixer (Model 6-800, Hobart Manufacturing Co., Philadelphia, PA). The Hobart was fitted with a flat paddle used to mix cake batter, and the mixture of base mix and vitamin C solution was added with low-speed mixing (setting No. 1) over a period of 15 sec. The vitamin C was added to the hot riced potatoes at a level of 25.1 g AsA equivalents/100 kg, or 251 ppm on an "as is" moisture basis (~80%). The mixing was continued at low speed for 5 min, and the batch was drum-dried over a period of about 45 min on a pilot scale single drum dryer at $5.5 \times 10^5$ Pa(gage) steam pressure and 2 rpm (Sullivan et al., 1985). The potato flakes (5–7% moisture content)

*Table 1—Retention of AsA, AsMP, and AsPP after addition to hot riced potatoes followed by drum-drying*

| Vit C source | Target level of AsA eq., ppm W.B. | Target level of AsA eq., ppm D.B. | Moisture of dry flakes, % | Level in potato flakes on D.B., ppm | Retention % |
|---|---|---|---|---|---|
| Blank | — | — | 5.5 | 0 | 0 |
| AsA | 251 | 1394 | 6.1 | 613 | 44 |
| AsMP | 251 | 1394 | 6.2 | 1227 | 88 |
| AsPP | 251 | 1394 | 6.0 | 1171 | 84 |

were placed in polyethylene bags and kept frozen about 5 wk prior to storage tests.

### Storage of potato flakes

Fortified potato flakes were placed in a desiccator over a saturated aqueous solution of lithium chloride, which gives 12% relative humidity at 25°C (Strolle and Cording, 1965). After 3 days, the moisture in the flakes equilibrated to 5.5%, and subsamples (15g each) of potato flakes were weighed into individual small bags made from oriented polypropylene. The bags were sealed with a thermal sealer, and then stored at 25, 35, and 45°C for up to 12 mo. At a given time, one bag from each batch of flakes was removed and assayed for moisture and vitamin C.

The phosphorylated L-ascorbate appeared not to be uniformly distributed. Therefore, the fortified potato flakes (100g each) were removed from frozen (−20°C) storage after 8 mo, equilibrated to 5.5% moisture content, and then ground through a 30-mesh screen on a Wiley mill. After thoroughly blending the ground material, subsamples (15g each) were sealed in small, oriented-polypropylene bags. The bags were stored as previously described, and the loss of vitamin C determined at storage times up to 4.3 months.

### Vitamin C loss during reconstitution and holding mashed potatoes

Potato flakes were reconstituted to mashed potatoes by the method of Augustin et al. (1981). Water (80 mL) was brought to a boil in a pan, and butter (6.4g) and salt (1.5g) were added to the boiling water. The pan was removed from the heat, and cold milk (36.6g) was added followed by the flakes (27g). The mixture was first stirred gently with a fork and then fluffed for 3 min.

After preparation, the mashed potatoes were held on a steam table at about 95°C. Samples (~20g "as is") were assayed for L-ascorbic acid equivalents immediately after removing from the steam table at 15, 30, and 60 min. The temperature of the mashed potatoes increased from 48–56°C immediately after reconstituting to 75–85°C after holding on the steam table 60 min.

## RESULTS & DISCUSSION

### Vitamin C losses during fortification

The steps of adding vitamin C to the riced potatoes and drum drying destroyed 56% of added AsA, 12% of AsMP, and 16% of AsPP (Table 1). These data on AsA losses agreed with the ~50% loss reported for those processing steps in a commercial operation (Augustin et al., 1979), but were somewhat higher than the ~30% loss reported for a pilot-plant operation (Cording et al., 1961). Loss of AsA occurs during the cooking and ricing steps, with little loss during drum drying (Sullivan et al., 1985). The potato flakes produced in the present investigation contained 613, 1227, or 1171 ppm, respectively, of AsA, AsMP, or AsPP, (AsA equivalents on a moisture basis of ~5.5%). The blank sample of potato flakes was devoid of AsA.

### Losses of vitamin C during storage

Commercial potato flakes were found to have a moisture content of 5.5%, so the potato flakes in this work were equilibrated to that moisture level prior to storage. The stability of AsA in stored potato flakes is shown in Fig 1. After 12 mo, 80% of AsA was lost at 45°C, 70% at 35°C, and 66% at 25°C.

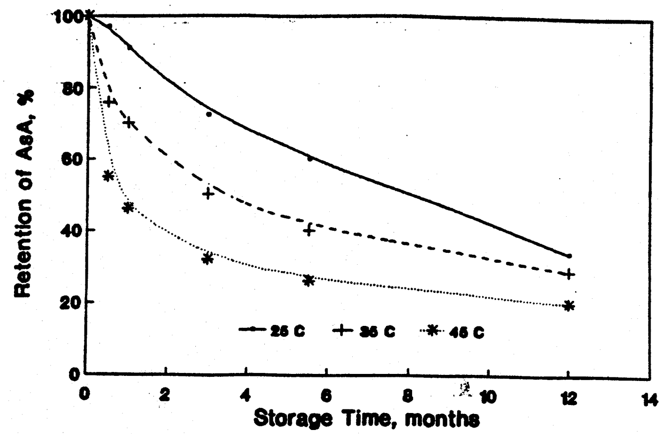


*Fig. 1—Retention of L-ascorbic acid (AsA) in potato flakes stored in oriented polypropylene bags. The starting level of AsA was 613 mg/kg (dry basis).*

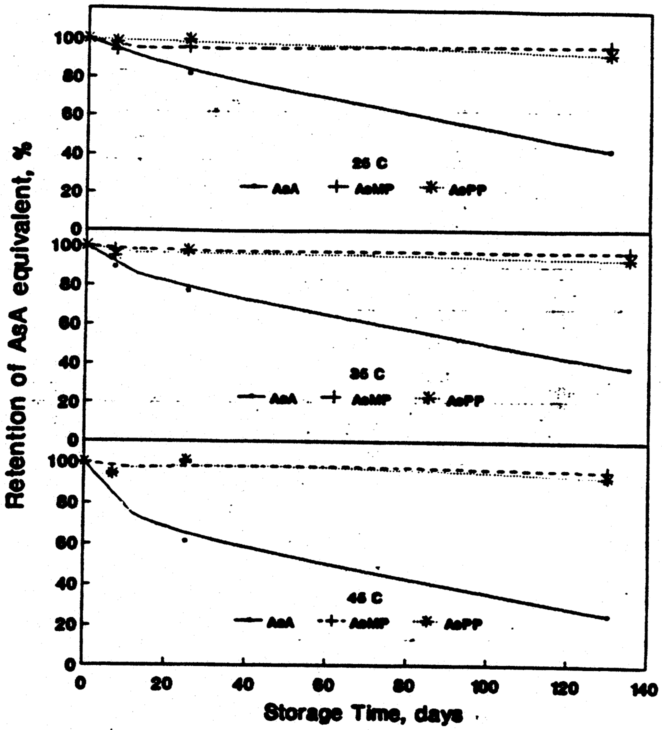


*Fig. 2—Retention of L-ascorbic acid (AsA, initially 613 ppm, d.b.), L-ascorbate 2-monophosphate (AsMP, initially 1290 ppm d.b.), and L-ascorbate 2-polyphosphate (AsPP, initially 1171 ppm, d.b.) in ground potato flakes stored at 25°C, 35°C, and 45°C in oriented polypropylene bags.*

Losses were much more rapid during the first 3 mo storage compared to the last 6 mo.

The storage stability of AsMP in the potato flakes over a 0–12 mo period ranged from 0–20%. The data points (not shown), failed to generate smooth curves, indicating that AsMP was not uniformly distributed in the flakes. The data for storage stability of AsPP in potato flakes also indicated nonuniform vitamin distribution. We speculate that somehow AsMP and AsPP became insoluble when added to the base mix, causing the nonuniformity.

To circumvent these distribution problems of AsMP and AsPP, samples of frozen potato flakes were warmed to 25°C, ground, mixed, and stored again. Note that no loss of vitamin C activity occurred during the 8 mo frozen storage.

After 130 days or 4.3 mo storage, 58% AsA was lost from the ground potato flakes at 25°C (Fig. 2), 62% at 35°C, and 75% at 45°C. In contrast, AsMP and AsPP were essentially stable in

*Table 2—Retention of vitamin C during preparation and holding of mashed potatoes made from potato flakes*

| Form of vit C | Theoretical[a] level in mashed potatoes on W.B. ppm | Retention of AsA eq. in mashed potatoes held on steam table, W.B. | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 0 min | | 15 min | | 30 min | | 60 min | |
| | | ppm | % | ppm | % | ppm | % | ppm | % |
| AsA | 120 | 120 | 100 | 48 | 40 | 27 | 22 | 14 | 12 |
| AsMP | 280 | 286 | 102 | 277 | 97 | 271 | 95 | 260 | 91 |
| AsPP | 211 | 215 | 102 | 195 | 91 | 189 | 88 | 183 | 86 |

[a] Theoretical level calculated from level of AsA, AsMP, and AsPP in dry potato flakes, which was 613, 1227, and 1171 ppm, respectively.

*Table 3—Stepwise losses and overall losses (%) of vitamin C from production to consumption of fortified mashed potatoes[a]*

| Vit C source | Loss (%) of AsA equivalents in food delivery system | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Preparation of potato flakes[b] | Storage of ground potato flakes for 4-mo[c] | | | Mashed potatoes on steam table[c] | Overall loss[b] | | |
| | | 25°C | 35°C | 45°C | 30 min | 25°C | 35°C | 45°C |
| AsA | 56 | 58 | 62 | 75 | 78 | 96 | 96 | 98 |
| AsMP | 12 | 4 | 2 | 4 | 5 | 20 | 18 | 20 |
| AsPP | 16 | 8 | 6 | 7 | 12 | 32 | 31 | 31 |

[a] The dried ground potato flakes were stored 4 mo, and reconstituted mashed potatoes were held 30 min on a steam table.
[b] Losses were calculated based on the initial level of AsA equivalents added when preparing the potato flakes.
[c] Losses were calculated based on the level of AsA equivalents determined immediately before the step in question.

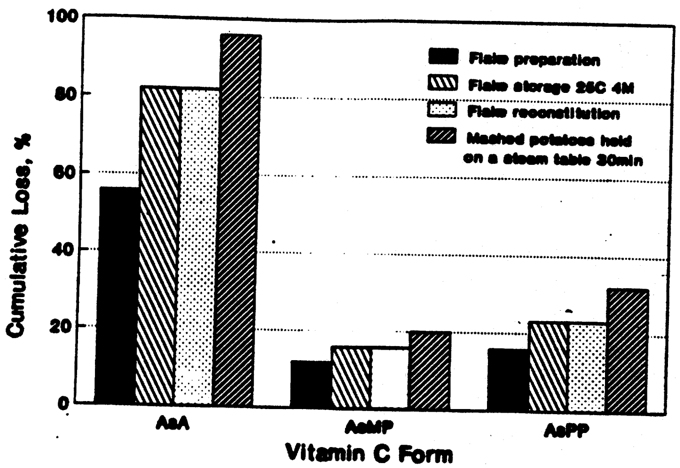


*Fig. 3—Cumulative losses of three forms of vitamin C at each step between production and consumption of fortified mashed potatoes.*

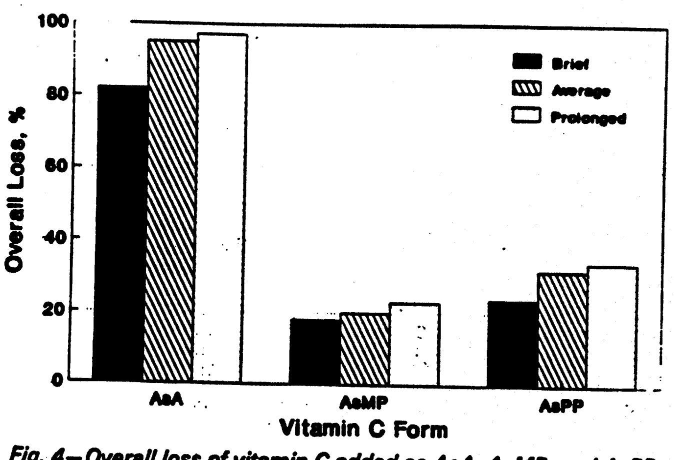


*Fig. 4—Overall loss of vitamin C added as AsA, AsMP, and AsPP under different periods of storing the ground flakes and of holding the mashed potatoes on a steam table. A 56%, 12%, and 16% loss of AsA, AsMP, and AsPP, respectively was assumed at the mixing and drying steps, and no loss during reconstitution. Brief—storing ground flakes 1 mo at 25°C and holding hot mashed potatoes 15 min; Average—storing ground flakes 4.3 mo at 25°C and holding hot mashed potatoes 30 min; Prolonged—storing ground flakes 4.3 mo at 25°C and holding hot mashed potatoes 60 min.*

the ground potato flakes. Only 3–5% vitamin C was lost in 4.3 months at 25, 35, or 45°C when AsMP or AsPP was the source of vitamin C. These results indicate that AsMP (and AsPP) also would be much more stable in stored potato flakes.

## Stability of vitamin C during reconstituting and holding mashed potatoes

No loss of AsA, AsMP, and AsPP were found during reconstitution of the mashed potatoes (Table 2). The nonfat dry milk added during reconstitution may have contributed a small amount of AsA (Augustin et al., 1981), but we ignored that in our calculation. Bring et al. (1963) reported ~70% loss of indigenous AsA in mashed potatoes reconstituted from potato flakes made commercially. In our study, 60% of AsA was lost in the mashed potatoes after holding on the steam table for 15 min, 78% after 30 min, and 88% after 60 min. AsMP and AsPP were much more stable during holding of the mashed potatoes on the steam table. Only 9% of AsMP and 14% AsPP were lost after 60 min. Augustin et al. (1981) reported a 63% loss of AsA (initial level 1,800 ppm AsA in dehydrated potatoes, d.b.) in mashed potatoes held for 1 hr on a steam table, and Ang et al. (1975) reported a 49% loss of AsA (initial level 208 ppm in dehydrated potatoes, d.b.) when mashed potatoes were held for 1.5 hr on a steam table. The increased loss of AsA in our work (78% after 1 hr holding) may have been due to the different assay methods. Our method of assay was specific for AsA, while other workers used colorimetric methods that are subject to interference by other reducing substances, such as sulfite, in potatoes.

Mashed potatoes contain entrained air and ~77% moisture content and they are held at a high temperature (75–85°C). Those conditions explain the high losses of AsA in the mashed potatoes. AsMP and AsPP were retained much better than AsA because of their stability towards oxygen and the denaturation of phosphatase enzymes during processing. For unknown reasons, AsMP appeared to be more stable than AsPP during preparation of the potato flakes and during storage of the mashed potatoes on a steam table.

## Combined losses during preparation/storage of potato flakes and during reconstitution/holding mashed potatoes

When a food is fortified, the nutrient must be stable during processing and storing of the packaged food and during the final preparation and presentation of the food in the home or institution. In the case of L-ascorbic acid, we demonstrated again that the stability during the final stages of food preparation is especially important, as noted previously by Erdman and Klein (1982) and Augustin et al. (1981).

Fortification of instant mashed potatoes with vitamin C has potential losses at four points between production of flakes and meal-time presentation of mashed potatoes. Losses can occur during (1) production of the flakes, (2) storage of flakes, (3) reconstitution of mashed potatoes, and (4) holding the mashed potatoes prior to serving. Table 3 and Fig. 3 show the losses of vitamin C that occurred during those steps under average conditions, which included storing the ground potato flakes for 4.3 mo at 25°C, and holding the mashed potatoes 30 min on a steam table.

Extensive losses of AsA were incurred at all points, except during reconstitution. Overall, 96% of AsA was lost during preparation and storage of the fortified ground potato flakes and during holding of the reconstituted mashed potatoes on the steam table. Adding AsA at a level of 251 ppm to the freshly riced potatoes gave a final level of 10 ppm AsA in the mashed potatoes at the point of consumption (after drying, storing, reconstituting, and holding). That level provides in a single serving (100g, "as is"), 2% of the adult RDA (60 mg) of AsA. If 100% of the AsA added to the potatoes had survived the food delivery system, a single serving would have provided 42% of the RDA.

In contrast, addition of AsMP or AsPP to the freshly riced potatoes at about 250 ppm AsA equivalents produced mashed potatoes at the point of consumption with a final level of 201 ppm or 171 ppm AsA equivalents, respectively (Table 3, Fig. 3). A single serving (100g) of those mashed potatoes would provide 34% or 29% of the RDA of vitamin C, respectively.

The combined loss of AsA was still severe (82%) when the dried ground potato flakes fortified with AsA were stored for 1 mo at 25°C and the mashed potatoes were held on the steam table for 15 min (Fig. 4). Under the most extreme combination of conditions of storing the dried ground potato flakes for 4.3 months and holding the mashed potatoes for 60 min on the steam table, almost all added AsA was lost. Fig 4 shows that the losses of vitamin C from fortified mashed potatoes containing AsMP and AsPP never exceeded 35% under the various storage and holding conditions.

## CONCLUSIONS

ALTHOUGH AsA may be the most cost-effective for fortifying a preserved food on the supermarket shelf, it may not be the most economical if one considers losses during food preparation and presentation in the kitchen or institution. When riced potatoes were fortified with AsA at a level of 250 ppm, about half the vitamin was lost during preparation of dehydrated flakes and the remaining half during storage of the flakes and holding of the reconstituted mashed potatoes on a steam table. Under the same conditions, 70–80% of vitamin C was retained at the time of ingestion when riced potatoes were fortified with 2-phosphorylated L-ascorbate.

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*DEHYDRATED CARROT TEXTURE*. . .From page 1128



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